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THE POTENTIAL FOR BIOFUEL PRODUCTION AND USE IN AFRICA: AN ADAPTIVE MANAGEMENT APPROACH.

Ogundiran Soumonni[1]
Susan Cozzens[2]

INTRODUCTION:

Biofuels are projected to play an increasingly important role in the gamut of sustainable energy options for the future. As countries such as the U.S.(corn ethanol), Brazil (sugarcane ethanol), Indonesia (oil palm ethanol), South Africa (maize, sugarcane) and others adopt and expand their biomass ethanol programs, many important questions have arisen in the media and elsewhere questioning the viability of biofuels. These articles have suggested that studies which had shown that biofuels would play a dominant role as an energy resource were wrong or exaggerated (Walsh 2008; Grunwald 2008). A review of assessments of the potential of corn ethanol reported that a positive net energy gain between the nonrenewable energy used to provide ethanol and the resulting energy from the fuel was obtained when ethanol co-products and the most recent data were included (Farrell et al. 2006). Another study has demonstrated that the net effect of the production of food crop-based biofuels through the clearing of carbon-rich habitats such as rainforests and savannas is to release more carbon dioxide than the reductions obtained by using biofuels (Fargione et al. 2008). It has also been reported that the diversion of existing crops or croplands into biofuels creates an increase in food prices, which further results in an accelerated rate of clearing forests and grasslands (Searchinger et al. 2008). Nevertheless, all three studies propose that cellulosic ethanol or bio-fuels derived from degraded crop land and waste biomass have the potential to reduce competition with food crops, minimize the destruction of habitats and reverse carbon debts that result from land clearing (Fargione et al. 2008; Farrell et al. 2006; Searchinger et al. 2008).

Africa currently has a relatively low level of biofuel development and investment with the exception of a few countries such as South Africa (Dynes 2008). This situation presents a need for more information and research required to address policy options, land requirements, standards and investment opportunities on the continent (Arungu-Olende 2007). Many countries such as Ethiopia, Malawi, Nigeria and Uganda already produce sugarcane for sugar as well as some cash crops like oil palm which can be used

[1] gtg725e@mail.gatech.edu;
[2] scozzens@gatech.edu
GEORGIA INSTITUTE OF TECHNOLOGY, SCHOOL OF PUBLIC POLICY. ATLANTA, GEORGIA U.S.A.

as biofuels. However, their development as energy crops is constrained by the environmental problems and food production issues that take precedence as highlighted previously. Indeed, a preliminary content analysis (done by our group) of the newspaper coverage of biofuels around the world from May 2007 to May 2008 revealed that the majority of news articles from Africa displayed a greater emphasis on the food crisis than on the emerging potential for biofuels development.

The objective of this paper is to analyze the currently dominant biofuels strategies and apply the principal elements of the concept of adaptive management to the selection, production and use of biomass ethanol in African countries. Given the difficulty of predicting the precise nature of the benefits and consequences of biomass ethanol to sustainable development, the adaptive management approach is pertinent as it emphasizes both substantive and procedural rationality. Substantive rationality is very specific, puts policy options on the table and tries to identify the quantifiable costs and benefits of the policy approach. Procedural rationality is the outcome of appropriate deliberation which does not yield a single decision point but guarantees that the policy decisions are made iteratively and that they are reversible (O'Neill, Holland, and Light 2008). It assists in the mitigation of unforeseen consequences that may disproportionately affect certain societal groups, particularly if they are not part of the decision making process. One implicit assumption that comes up in the discussion of biofuels is that all the stakeholders are primarily preoccupied by the energy crunch or by climate change. Some stakeholders are motivated by the economic profits from a new investment, others by jobs, others by environmental activism and a myriad other priorities, interests, preoccupations or lack thereof. In attempting to resolve the energy crisis sustainably, it is important to address such a system holistically, as a complex interaction of all the parts as opposed to adopting a reductive position such as linking the problem directly with the economy or with a purely ideological orientation. Furthermore, one individual or group’s wellbeing in one way may ultimately be counterproductive for the whole system, thus reducing the range of options for future generations. As will be shown subsequently, these are all factors that must be taken into consideration in designing a biomass ethanol program.

METHODOLOGY:

In order to evaluate the strategies based on this theory, the three central axioms of adaptive management will be tested, namely:

1.) Experimentalism: This method requires adaptive managers to take actions based on experience that are capable of reducing uncertainty in the future and allows room for incremental policy learning.
2.) Multiscalar Analysis: This axiom requires a holistic and integrated model of systems analysis that allows for the understanding of the environment as a complex interaction of parts. It also enables managers to keep track of the systematic consequences of actions as they emerge over the different temporal and spatial scales of the system. That is, short term, long term, small scale or large scale implementation.
3.) Place sensitivity: This requires a commitment to not only examine a given problem in its own geographical context but to also take into account the place-based values associated with that place. The basis for this is a participatory and

pluralistic process that includes all the relevant stakeholders in the policy or their independent representatives. (Norton 2005).

The first two axioms are emblematic of substantive rationality while the third one illustrates procedural rationality. Furthermore, the following steps have been taken in order to put these axioms into operation, namely:

4.) One country has been selected from each of the following four regional economic development blocs namely, ECOWAS (Economic Community of West African States), EAC (East African Community), SADC (Southern African Development Community) and ECCAS (Economic Community of Central African States).
5.) Overview of energy use and economic data of chosen countries (World Bank Reports, International Energy Agency (IEA), Energy Information Administration (EIA), United Nations Environment Programme (UNEP), etc).
6.) Overview of the dominant biofuel crops and non-crop sources that are available in the chosen countries (Same sources as above).
7.) Technology assessment of the available and potential technology infrastructure for the transformation of existing biomass sources into fuel as well as end use technologies.
8.) Policy assessment of the extent of public participation in energy policy strategies based on axioms of adaptive management.

The strategies will first be analyzed from the point of view of the production of crop and non-crop sources of biomass ethanol based on the capabilities of the countries. Secondly, the production of the biofuels will focus on the existing technical possibilities such as ethanol additives for replacing lead in gasoline (Thomas and Kwong 2001). This will also include a focus on the "Leapfrog" energy technologies (Goldemberg 1998; Brezis, Krugman, and Tsiddon 1993) that can be deployed to meet the energy requirements of less industrialized areas or regions. Finally, the extent of stakeholder participation in the decision making process, which is crucial to adaptive management, will be based on an analysis of the Energy Policy strategies of the regional economic organizations as published on their respective websites or assessments of those policies elsewhere.

CURRENT PRACTICES:

Africa is at a defining moment in trying to meet its development and energy challenges while trying to preserve its natural and cultural heritage and studies are now emerging to assess this impact (ABN 2007). The development of biofuels can be divided into two main processes. First, we have the production of the biofuel (crop and non-crop) sources and secondly, we have the end-use technologies which must be compatible with the fuels. In the case of production, we can further subdivide into traditional biomass for fuel such as wood or dung, and the large scale process of growing crops to produce fuel, which is alternatively known as agrofuels (ABN 2007). These crops are of three main types: bioethanol from sugar, sugar beet or maize; biodiesel from rapeseed, sunflower, oil palm or soy oil; cellulosic biomass ethanol from wood chips or crop wastes (Wetlands International). Large scale biofuels projects are becoming widespread in Africa with the twin intention of providing energy security and exporting biofuels for economic growth (ibid). Because the projects in Africa are at the early stages and few in-depth studies have been done, it is advantageous to analyze studies from countries with advanced biofuel programs. In the U.S. for example, 99 % of all biofuels comes from corn ethanol (Fargione et al. 2008). According to recent analyses, ethanol from corn that is produced on newly converted land in Iowa would require 93 years to repay the carbon debt resulting from clearing the grasslands; ethanol from corn on abandoned cropland would take 48 years; prairie ethanol on abandoned cropland would take 1 year while ethanol from marginal cropland would incur no carbon debt (ibid). We must also consider that growing demand for ethanol is leading to higher crop prices, which could lead farmers to till more acres and remove environmentally sensitive land from conservation programs thereby negatively impacting soil and water resources (Secchi and Babcock 2007). This suggests that only crops grown on marginal cropland in Africa would be sustainable.

Another touted benefit of biofuels, which when viewed through an integrated and holistic lens may legitimately be questioned is that it will lead to poverty alleviation (including small farmers). Most of the promotion of investments in biofuels so far, such as at the Biofuels Market Africa conference focused on transnational corporations (Argus 2007) and government agencies seeking to participate in their development or to learn from other countries and corporations (GreenPower 2007; UNIDO 2008). No community groups such as the various branches of the African Biodiversity Network (ABN), which seek to integrate biodiversity and livelihoods into climate change strategies were present. This allows for the possibility that the governments and partner industries may not have taken the time to fulfill all the sustainability criteria of experimentalism (incremental learning), multiscalar (valid for both small scale and large scale actions) and deliberations about place sensitivity with the local farmers and inhabitants of the areas they intend to make use of. Nevertheless, we can now take a more in-depth look at the current practices in the various economic regions with an emphasis on some specific countries.

<u>REGIONAL BIOFUELS POLICIES:</u>

The economic regions, whose agreements have not traditionally been binding on member states, have not adequately made explicit (on their respective websites) what the broad criteria for the sustainability of biofuels will be. The 2003 ECOWAS Energy Protocol for instance, only refers to biomass energy in its annex of energy materials and products in terms of primary biofuels such as fuelwood in the form of logs, twigs or billets and charcoal (ECOWAS 2003). The main stakeholders in the ECOWAS Protocol include the member states, national and multinational companies and international arbitration agencies such as the World Trade Organization (WTO). The East African Community has not published its energy strategy on its website and only Uganda was found to be developing oil palm for biofuels in this economic region. The EAAC's strategy only mentions biomass to the extent that it is used as traditional biomass. The Southern African Development Community (SADC) has made its strategies and deliberations public but its last protocol dates to 2001 and only refers to traditional biomass as well. However, under its objectives for petroleum, it calls for new petroleum products or fuel specifications that could have a significant impact on the region. (SADC 2001). South Africa has seized on this provision to encourage the development of a regional biofuels program in which it will take on the lead role (RSA 2007). The South

African biofuels strategy subsequently calls for the integration of the SADC countries in terms of creating a regional fuel pool and regional biofuels specifications (ibid). The Union of the Arab Maghreb (AMU) of North African states does not have a biofuels strategy largely because this region is not a significant producer of most of the crops that are typically proposed for biofuels production. Furthermore, it consists of major oil producers who could more readily use petrochemical-derived MTBE (methyl tertiary butyl ether) as an additive for blending with gasoline (Thomas and Kwong 2001). Egypt, however, produces sugar cane (ibid) and some of the other countries produce cereals.

The policies around biofuels are therefore currently being framed predominantly at the national level. Some aspects of selected national experiences are described below.

<u>ECOWAS: Benin</u>

Benin is a country whose economically active population (55%) is predominantly engaged in the agricultural sector (which was about 38% of the 2000 GDP). Furthermore, about 90% of agricultural output is produced by small, independent farmers. Only about 17% of the total area is cultivated and the main food crops are yams, manioc, corn (cereal), sorghum (cereal), rice (cereal), dry beans, sweet potatoes, sugar cane and millet (cereal) (Nationsencyclopedia 2008).

The main cash crops are cotton and oil palm, which is native to the wetlands of West Africa. Historically, the production and sale of oil palm with the government have been beleaguered by corruption and disagreement but even when private companies offered to buy palm oil directly from the communities at a higher price, they failed to pay and the communities bore the loss without support from the state (WRM 2007). The government is now seeking to establish oil palm plantations for biofuels on 300,000 – 400,000 hectares of land in the prime agricultural lands of the South of Benin and is also planning to find 3 million hectares for the scheme by 2011 (ABN 2007). This is where half of the country's population lives on approximately 7.7 % of the national area, which suggests that there will be competition with food crops. It has not been stated explicitly where this land will come from and it is unclear whether the interests of small scale farmers will be protected against those of the big industries (WRM 2007).

Furthermore, several hydrological studies have reported the observation of a 'climatic anomaly' which occurs through the disruption of the rainfall patterns with characteristically low rainfall- a phenomenon that started in the 1980s in Togo, Cote d'Ivoire and the South of Benin (Gauthier et al. 1998). This is a likely contributor to the reduced oil palm production and sales stated above because low rainfall is attributed to reduced oil palm pollination and therefore lower yields (USDA 2004). The decision by the government to seek land for biofuels in precisely this area does not appear to have taken these climatic changes into consideration.

This policy therefore appears to have been inadequately investigated from a substantive point of view, in the sense that little experimentalism is taking place and the scalar dimension has not been accounted for. From the procedural perspective, despite the fact that the government is democratically elected and widely popular, the plans, projections and deals have occurred without any legislation guiding biofuels development. In addition, the discourse around biofuels has been framed squarely in terms of profit maximization by the government with projected oil palm production destined entirely for export and without mention of domestic use (ABN 2007).

ECCAS: Cameroon

Cameroon is a country whose main source of economic growth was agriculture (which was about 43% of the 2001 GDP) until it was replaced by oil starting in 1978. However, it remains the predominant activity of 68% of the population (1999) on about 15% of the arable land. The main food crops are plantains, manioc, corn (cereal), sorghum (cereal), dry beans, sweet potatoes, potatoes, millet (cereal) and rice (cereal). The main cash crops include coffee, cocoa, sugarcane, cotton, rubber and an increasing production of palm oil. (Nationsencyclopedia 2008).

Governmental programs and foreign capital have largely supported the industrial plantation of oil palms which aims to produce at least 250,000 tons of oil palm by 2010 on 5,000 ha per year. The biofuel boom has also stimulated the expansion of this industry in Cameroon. It is carried out by five large companies, the largest of which is SOCAPALM which is reported to expand at the cost of forests traditionally used by local populations as well as the seizure of land without compensation with the collusion of corrupt government officials. It is also reported to cheaply employ workers from other regions, accommodate them in guarded camps on the plantation and dispose its factory waste in nearby streams causing health hazards (Gerber 2006)

Despite the emergence of climatic disruptions in neighboring countries that could affect oil palm production, Cameroon has been unaffected and continues to receive abundant rainfall (Gauthier et al. 1998). Nevertheless, the control of the industry seems to be exploitative and lacks transparency. Here, we can infer that while one aspect of the substantive policy of oil palm development can be defended (abundant rainfall), the procedural imperative is hardly in place.

EAC: Uganda

Uganda's agricultural sector provided 36% of the country's GDP in 1998 and accounted for about 81 % of its economically active work force. Its major food crops are millet (cereal), cassava, sorghum (cereal), bananas, rice (cereal), maize (cereal), plantains and beans. Its main cash crop is coffee. Others include sugarcane, tobacco, cotton and tea (Nationsencyclopedia 2008).

Oil palm has also become an important cash crop with a large project designed to cover 26,500 hectares and 140,000 tonnes of palm kernel oil already dedicated to the largest East and Central African manufacturer of vegetable oils, fats, soaps and margarine, by a company known as BIDCO Oil Refineries Ltd (WRM 2005). However, residents of the Bugala islands in the Kalangala district (the area anticipated) and some members of parliament are opposing this project which they say is taking place on one of the few pristine natural large scale forests in Uganda. The island of Bugala also has one of the most unique eco-systems worldwide (WRM 2005). The president and government ministers are reported to have characterized the critics of their deforestation programs as romanticists and as unpatriotic (Serumaga 2006).

We can therefore conclude that neither the substantive (clearing of forests) nor the procedural (insufficient deliberation) approaches have been carried out.

SADC: Republic of South Africa

South Africa has a dual agricultural economy whereby the majority of agricultural workers are engaged in subsistence but at the same time, there exists a commercial sector that is highly industrialized. Agriculture has a declining share of 5% of the GDP and employs about 30% of the work force. About 13 % of the total area is arable land but the country experiences uneven rainfall, which represents a constraint to its agricultural production. South Africa's main food crops include maize (cereal), wheat (cereal), barley (cereal), sorghum (cereal) and many fruits, in particular grapes for its large wine industry. It also produces sugarcane and is the 10^{th} largest producer of sunflowers in the world. Other cash crops include cotton and tea and it also has one of the largest man-made forest plantations in the world (Nationsencyclopedia 2008). While forestry products represent an important part of the national economy, some of the large-scale plantations have been consuming scarce water resources while having negative impacts on rural communities and natural biodiversity (Menne 2006).

The initial focus of the South African biofuels strategy is anticipated to be on local development in order to allow the South African industry to mature but the stated goals are job creation and economic growth (RSA 2007). The small initial scale is also accompanied by a short 5-year pilot program that was originally designed to achieve a 4.5% penetration level of biofuels in the national supply but was reduced to 2% due to widespread criticism (Esterhuizen 2007). Crops such as maize and plants like jatropha were excluded based on food security concerns and pending further research. Sugar cane and sugar beet were proposed for bioethanol while sunflower, canola and soya beans were proposed for biodiesel (RSA 2007). However, it should be pointed out that a study has demonstrated that soybean and sunflower required 27% and 118% more fossil energy respectively than the biodiesel produced (Pimentel and Patzek 2005). While these figures are partly the result of physical and chemical factors in the U.S. such as a low fraction of sunlight being captured by sunflower and soybeans and the relatively low yields of the plants (ibid), a similar study applied to South African conditions would be required before pursuing these crops in the absence of any experience with them. Despite the apparently modest scale of the biofuels initiative, it does target "underutilized arable land" and states that necessary measures have been put in place to guard against food inflation. Furthermore, it calls for using almost all of this land for full production once a firm market has been secured (RSA 2007). The last proposal is highly speculative given the competitive and risky nature of deregulated markets and is only based on an expectation that the ethanol price will be lower than that of gasoline (ABN 2007; Meyer 2008). The land issues around rural development are also projected to be enhanced by the biofuels industry while water resources are to be distributed based on best practices outlined for food crops. The strategy supports negotiating with the oil industry to use its infrastructure to accommodate biofuels, thereby efficiently leading to a mandatory uptake when their supply can be guaranteed. The government's industrial biofuels strategy was open for public comment until a specified date.

A group of 28 community-based groups, several NGOs, individuals, farmer organizations and especially the rural communities expressed dismay alleging that the strategy fuelled "land grabs' or expropriation because deals had already been struck for large scale export to the European Union. This had resulted in the coercion of farming communities to give up their "existing diverse food gardens and communal grazing lands for a pittance for industrial plantations of soya, maize and canola" (Mtembu et al. 2007). These groups called for a moratorium on large-scale biofuels projects and the development of a strategy that addresses energy poverty within an integrated energy framework that includes genuine participation of the rural population, especially women. They called for decentralized community-owned biofuels plants to guarantee food and energy security and specifically requested for the exclusion of staple food crops, large plantations of monocultures, or even genetically engineered plants on prime agricultural land (ibid).

We can say that despite the contentious conclusions of the government's substantive policy, procedural rationality has been observed to a larger extent than in the other countries selected.

IDEAL SCENARIO:

Given the energy crunch, there is a tendency on the part of observers and stakeholders to tap into the popular sentiment of the 'next big thing'. Until recent doubts surfaced in the press, biofuels appeared to be the panacea of the world's energy problems. Now that some counterproductive effects of biofuels are emerging, one important lesson that can be learned is that while they can still play an important role in the energy options for the future, one or two sources will not suffice but rather an ongoing adaptive process will be required to successfully implement biofuels. In other words, the maxim, 'one size cannot fit all' will have to be applied here. In this section, a more ideal situation is proposed in which environmental, economic and policy development can take place with better implications for sustainability.

Again, focusing on substantive rationality, a consensus is emerging among energy and environmental scholars that cellulosic (non-grain plant materials) ethanol and waste wood products are the dominant biofuel option to complement or substitute for energy crops (Lynd et al. 2007). These bio-fuels should be derived from degraded crop land so that they do not compete with food crops, create carbon debts from land clearing or damage soils and water resources through overuse and harmful chemicals. (Fargione et al. 2008; Farrell et al. 2006; Searchinger et al. 2008). Because the conversion of cellulose into ethanol requires advanced biotechnology and the use of degraded crop lands produces lower yields, such a suggestion implies that biofuels still face significant hurdles towards their full adoption. However, the slower, adaptive pace of biofuels development may in fact be a small price to pay for sustainable energy use given that the rush to clear forests and grasslands may have created carbon debts that will take 50 to 100 years to be recovered if such activities stopped being carried out almost immediately.

There are many sources of feedstock for biomass ethanol production such as wood chips, municipal solid waste, energy crops of fast growing trees and grasses or food crop wastes (USDOE 2001). One such source which is very promising is the use of corn stover, that is, the stalks and leaves excluding the grain, for ethanol production (ibid). Since it is already available in the same areas that produce corn grain, it is accessible to plants that produce ethanol from corn starch (USDOE 2001), which would reduce the travel time, costs and energy used in transportation. In China, scientists have recently developed a method of producing clean biogas fuel from rice crop stems and leaves (straws) (Hepeng 2008). These crop wastes are usually left behind after harvesting and later burned, thereby releasing carbon dioxide into the atmosphere (ibid). It is therefore reasonable that corn, rice and other cereals such as sorghum or millet, widely grown in Africa for food could be used in a similar manner. Another important advantage of these sources is that it does not significantly change the place orientation of farmers who already cultivate these crops. While the profits may not be as large as selling corn grains or rice grains for fuel (which is unsustainable), it should provide added income to the farmers while having little or no effect on prices or on carbon emissions. The harvesting of corn stover must nevertheless be carried out adaptively to ensure that there are no problems with erosion or soil quality (USDOE 2001; Graham et al. 2007) but in those cases where the wastes are routinely burned, this would seem appropriate. Lines of communication can also be opened with local farmers (as is done in the U.S.) asking them to work with the local Natural Resource Conservation Service to give them advice such as how to experiment with stover on a small field (USDOE 2001). In addition, they can gain advice on how to establish stover ethanol plants based in the communities. It becomes clear that such a process would be inherently experimental (allowing for policy learning) and easily reversible if the conditions for production turn out to be unsuitable. It would also have had the twin role of maximizing profit and also maintaining the constitutive values that would preserve the identity of the place as a community (Norton and Steinemann 2001) – in this case, of the farmers.

If we adapt this idea exclusively to the cereal crops used in the selected African countries, we can estimate the amount of ethanol that can be produced if just the waste of these crops is converted, using the U.S. corn stover model as shown below in Tables 1-5.

<u>Estimated Energy Potential for Countries:</u>

ECOWAS (Economic Community of West African States):

Table 1. Republic of Benin

Population	6.92 million
Petroleum Consumption	17.13 thousand barrels
Agricultural Production (Cereals)	1013 tons (metric)
Cash Crop Production	Sugarcane (6 Tons)
Arable Land	2380 kHa total, 265 kHa perm. crops
CO_2 Emissions	2.27 million tons

ECCAS (Economic Community of Central African States):

Table 2. Republic of Cameroon

Population	16.3 million
Petroleum Consumption	24.5 thousand barrels
Agricultural Production (Cereals)	1365 tons (metric)
Cash Crop Production	Sugarcane (118 ktons)
Arable Land	5900 kHa total, 1200 kHa perm. crops
CO_2 Emissions	6.81 million tons

EAC (East African Community):

Table 3. Republic of Uganda

Population	7.07 million
Petroleum Consumption	11.57 thousand barrels
Agricultural Production (Cereals)	2625 tons (metric)
Cash Crop Production	Sugarcane (22 tons)
Arable Land	5060 kHa ttotal, 2100 kHa perm. crops
CO_2 Emissions	1.62 million tons

SADC (Southern African Development Community):
Table 4. Republic of South Africa

Population	45.214 million
Petroleum Consumption	504.91 Thousand barrels
Agricultural Production (Cereals)	12352 ktons (metric)
Cash Crop Production	Sugarcane (19095 ktons)
Arable Land	14753 kHa Total, 959 kHa perm. crops
CO_2 Emissions	423.81 million tons

Sources: 1.) Energy Consumption (daily), CO_2 emissions (EIA 2006)
2.) Cereals production (daily food), Cash Crop Production, Arable Land, Population (FAO 2004)

<u>Estimated Production From Agricultural Residues:</u>
Energy Content of agricultural residues (range due to moisture content) = 10 - 17 GJ/ton (ORNL figure (ORNL 2008)).We use a conservative value of 10 GJ/ton
Assuming conservative figure of 10 GJ, then Energy content = Agric. Production x 10 J
1 Barrel of Oil = 6.1 GJ
1 Barrel of Oil = 159 liters
Ethanol energy content = 23.4 MJ/liter
We assume that the mass of corn stover extracted from the crop is roughly the same as the mass of corn grain, that is a 1:1 ratio (Graham et al. 2007)
We also assume that 30 % of corn stover can be removed inexpensively while taking into consideration wind erosion, soil erosion, moisture and nutrient loss (Graham et al. 2007), which we then generalize to all cereals.

Table 5. Estimated Biofuel Production from Cereal Crop Waste

	Petroleum Consumption (Barrels)	Equivalent Volume (liters)	Cereal production (Tons)	30 % Crop Waste (Tons)	Equivalent Volume (liters)	% Vol Biofuels
Benin	17,130	2,723,670	1,013	303.9	129,871.79	4.77
Uganda	11,570	1,839,630	2,625	787.5	336,538.46	18.29
South Africa	504,910	80,280,690	12,352	3705.6	1,583,589.74	1.97
Cameroon	24,500	3,895,500	1,365	409.5	175,000	4.49

The estimates shown in Table 5 above show that if a sustainable amount of cereal crop wastes are converted to ethanol (Graham et al. 2007), the countries selected could displace about 2% to 18% by volume of their petroleum consumption depending on the energy profile of the countries. For Benin, South Africa and Cameroon, this is quite consistent with the 2 % used to increase the octane or efficiency rating of gasoline in the U.S. (Farrell et al. 2006) and in the case of Uganda, nearly the 20% levels used for ethanol blends in Brazil (Goldemberg et al. 2004). Even though this is a thought experiment or an ideal that is restricted to cereals, it is based on established data. It also strongly suggests that the crop waste model is a viable sustainable approach to biofuels production that African countries could start experimenting with prior to launching large scale projects that could cause irreversible damage in several ways.

Plantation Agriculture (Sugarcane):

In addition to the percentage of fossil fuels that could potentially be displaced by crop waste-based ethanol, all the countries highlighted in Tables 1-4 are producers of sugarcane, which can also add to their sustainable biofuels production. Given the unfavorable fiscal characteristics that typify the sugar industry in many developing countries such as the price of sugar on the world market or the value of international subsidies, Caribbean and African nations have not typically achieved economic competitiveness through sugar production (Bobb 2005). Some of the existing sugar plantations could therefore be diverted towards ethanol production, thereby increasing profitability and likely maintaining the place-based orientation and values of farmers in this industry. A country like Brazil has a long ethanol learning curve that African nations could learn from (Goldemberg et al. 2004). Other extant and previously unprofitable cash crops can similarly be potentially regenerated and intensified without clearing new lands, thus turning “lemons into lemonade”. Again, as in the case of cereals, the sugarcane bagasse, which is the biomass remaining after the juice has been extracted from the cane, can also be a source for ethanol.

Adaptive Biofuels Technologies:

We can now turn to the use of biofuels in their technological application, particularly in the area of transportation. It has been reported that 3.4 billion gallons of ethanol or 2 % by volume of all gasoline in the U.S. is used to blend the gasoline to achieve a higher octane rating or efficiency (Farrell et al. 2006). One main advantage of using gasoline blends is that it replaces lead, which is harmful to populations exposed to it, particularly adverse neurological effects on children (Thomas and Kwong 2001). Lead has been phased out in much of North America and Europe but not in Africa and it has been shown that Africa can easily produce enough ethanol from sugarcane to replace all the lead (ibid). In addition to being used as an octane enhancer, it can also be used as an oxygenated additive to gasoline, which can be blended in a proportion of 20-26% by volume of anhydrous ethanol, creating a mixture known as gasohol (Goldemberg et al. 2004). This represents an incremental yet important change of reducing the carbon monoxide and other toxic emissions of gasoline by gradually mixing it with more ethanol instead of trying to entirely replace gasoline with another fuel. The use of biodiesel from waste oil has also been reported, which can be blended by more than 20 % into diesel and is non-toxic, biodegradable and has lower emissions (Arungu-Olende 2007). Biodiesel is being used in different kinds of diesel-powered equipment such as jet engines, cars trucks or buses (ibid). From the substantive point of view, this approach is iterative, reversible and any adverse consequences can quickly be identified over different dimensions of space or time. It therefore satisfies at least two of the axioms of adaptive management namely incrementalism and multi-scalar analysis. We can also cite here, the Songhai Center in Benin, a pilot center for the research, development, training and promotion of sustainable agricultural practices, which consistently participates in conferences on bioenergy on the continent (SONGHAI 2008; UNIDO 2007). This center has established a biogas methane system where all the animal excrements, crop wastes and sewage are used as a source of energy to run parts of the center. Among other methods and objectives, its charter requires the hybridization of modern and traditional methods to use local resources effectively, the encouragement of communal and individual initiatives and the inclusion of diverse opinions (SONGHAI 2008), therefore making it a model of adaptive management.

Other adaptive technologies that can be used include flex-fuel vehicles that allow cars to alternatively run on gasoline or ethanol blends. Used vehicles can be imported from countries that already have them in use and new ones can be imported from countries that have the manufacturing capability but have not yet had significant market penetration.

Cellulosic ethanol technologies, some of which are still emerging, represent an opportunity for technological leapfrogging that African countries could borrow and adapt to local conditions with adequate planning.

POLICY RECOMMENDATIONS FOR BRIDGING THE GAP BETWEEN THEORY AND PRAXIS:

Some policy recommendations for bridging the gap between the best intentions of energy planners in the area of biofuels and the practice can be highlighted from the previous analyses of current and ideal scenarios. Some of these include:

1. Mass Education and Awareness of the Subject: While it is likely that the contentions made by the citizens groups, forest preservation groups and environmental groups may be contested by democratic governments, the debate should nevertheless move from the experts to the general public in order to avoid 'towering' or a perspective-limited discussion of the subject matter.
2. Lines of communication should be developed or strengthened between the ministries of energy/environment, local natural resource conservation services and farmers on specific ways to experiment with and adopt cellulosic corn stover and other crop wastes. This will give both sides valuable information about both the technical and place-based issues surrounding the harvesting of crop wastes.
3. As a consequence of the first two proposals, an increasingly informed public participation should lead to political representatives presenting and promoting the concerns of their constituents in the national parliaments.
4. When policies are enacted, the representatives should install a mechanism such that new policies are not adopted while previous policies that compete or counteract with the present goals remain in place thereby avoiding a type of 'governing confusion' (Brown and Chandler 2008). Such a mechanism could involve suspending the counterproductive measures while awaiting a review so as not to exacerbate any damage that may be done in the interim.

5. Establish minimum sustainability standards for biofuels within the economic regions and continent-wide as a basic guideline for countries and impose some penalties for non-compliance.
6. Much more stringent requirements for the clearing of forests, grasslands or arable lands for biofuel crop production should be instituted at the national levels given that these activities are difficult to reverse and contribute to carbon emissions.
7. While large scale projects and approaches can be attractive, there should be increased support for localized biofuel development projects because these are more manageable, more easily reversed, benefit the local communities economically and are more likely to be in accordance with their cultural values. In so doing, specific and general lessons can be learned and this will help in dealing with the mitigation of unforeseen consequences.

CONCLUSION:

A survey of African regions and selected countries within them shows that their push towards biofuels does not yet follow a sustainable path. While there are a few sustainable pilot projects in place, most government-run programs appear to be motivated by economic growth for their countries to the exclusion of some of the other issues that are central to the well-being of the affected communities and to the ecosystem. The axioms of adaptive management have been applied to biofuels policy in Africa in order to underscore some of the issues that could prevent or lead to a more sustainable energy future. These require a management and governance system that is essentially experimental with respect to the core science as well as energy and environmental policies. They also necessitate the practice of procedures that take into consideration the place orientation and cultural values of the people living in a particular geographical location. Lastly, Africa has a significant potential to develop its biofuel resources, which could contribute to its energy portfolio and help decelerate the pace of climate change. If the new adaptive techniques prove more productive and benign than the old, then the technologically lagging African nations have a chance to use them more widely, gain more experience with them and thereby effect a leapfrogging of technological leadership in this area (Brezis, Krugman, and Tsiddon 1993), as is already the case with Brazil.

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